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Impact of explicit information on implicit motor sequence learning in acute stroke

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Introduction

Stroke is defined as a rapidly developing clinical sign of focal disturbance of central function of presumed vascular origin & of more than 24-hours duration1. Clinically a variety of deficits are possible including changes in the level of consciousness & impairment of sensory, motor, cognitive , perceptual & language functions2. Although it is unequivocal that the extremities contra lateral to the unilateral cerebral lesion are more affected than the ipsilesional extremities, there is now a large body of research that suggests that the ipsilesional extremities are not normal often clinically assumed as "the non affected side" ,particular to the upper extremity there is increasing evidence of sensory-motor control deficits on the ipsilesional side3. These ipsilesional deficits may reflect motor control deficits that are masked on the contralateral side by hemiplegia and hemisensory loss3.

The non-dominant hemisphere plays a primary role in the function of complex visuo-spatial accuracy, whereas the dominant hemisphere is mainly involved in the motor control of bilateral upper limbs as well as the performance of complex tasks. Although the cause of ipsilesional movement abnormalties have not been elucidated accurately, several possible mechanisms have been suggested i.e. the injury of the uncrossed corticospinal system, inhibitory transcallosal influence on the unaffected hemisphere, the different roles of side-to-side hemispheric function depending on the specific properties of the task & bilateral hemispheric processing for high cognitive activity4. In persons with stroke, deficits in targeted movements, compared with comparison groups, have been identified in the ipsilateral extremities, even when clinical measures of the upper extremities reveal little or no deficit5.

Rehabilitation, for patients, is fundamentally a process of relearning how to move in order to carry out their needs successfully. This statement points out to the fact that practice or training leads to improvement of skills after hemiparesis. Improvement with rehabilitation increases with the amount of training and relates mostly to the task practised during therapy with little generalization to other motor tasks, although it has been suggested that retention of motor learning is best accomplished with variable training schedules. It has been found that after local damage to the motor cortex, rehabilitative training can shape subsequent recovery related reorganization in the adjacent intact cortex, thus showing the importance of learning for recovery of function7. Several rehabilitation approaches are based on theories of motor learning. These include impairment oriented-training (IOT), constrained induced movement therapy (CIMT), electromyogram (EMG) triggered neuromuscular stimulation, robotic interactive therapy and virtual reality (VR).

Learning has been described as the process of acquiring knowledge about the world, whereas motor learning has been described as “a set of cognitive processes associated with practice or experience leading to relatively permanent changes in the capability for producing skilled action”. There is subtle difference between motor learning and motor performance. Former defined as a relatively permanent change, whereas the latter defined as a temporary change in motor behaviour seen during practice sessions8. Memory is the outcome of learning, including the retention & storage of that knowledge or ability. Memory storage is often divided into short & long-term components. Short-term memory refers to working memory which has a limited capacity for information and lasts for only a few moments such as when we remember a phone number only long enough to dial it and then forget it. Long term memory is intimately related to the process of learning and it can also be seen as a continuum8. Learning and memory are not singular processes but are composed of many separate abilities. The broad categories of learning and memories can be subdivided into two main types – Explicit & Implicit9. Explicit learning may be assessed directly by testing memory for factual knowledge (eg. Recognition and recall). Implicit learning is a broad term used to describe the acquisition of abstract knowledge without awareness of learning. Perhaps the most common use of instructions is to inform the learner about the goal of the task and what needs to be learned to achieve that goal. With these instructions, the learner can engage in explicit learning. For example during sit to stand the therapist may teach a patient who is having difficulty from sitting to standing a specific sequence; first move to the edge of the chair, lean forward, then stand up. In contrast, in implicit learning, the goal is not presented to the learner. Implicit learning is inferred by observing changes in skilled movement relative to some baseline performance, in this case improved performance is assumed to reflect the acquisition of knowledge about the task which is then manifested as faster and more accurate movements8, 10.

The explicit and implicit learning & memory systems differ fundamentally10. There is now substantial evidence that implicit learning and explicit learning are subserved by different neural substrates10. Strong evidence for the dissociation of explicit and implicit memory comes from the finding that individuals with medial temporal lobe damage as in Huntington disease, Alzheimer disease and Multiple sclerosis suffer profound explicit deficits while retaining implicit memory capabilities11. In contrast, implicit learning is impaired in people with unilateral prefrontal cortex lesions, Parkinson’s disease and Cerebellar disease10. The functional neural network for implicit learning is thought to include the basal ganglia, prefrontal cortex and cerebellum. The network for explicit learning is thought to include the temporal cortex, hippocampus, and thalamus10. Despite their neuroanatomic seperation, it appears that the explicit and implicit sometimes develop in parallel and can profoundly affect one another9.

One of the most common paradigms used to study implicit learning is serial response time tasks. Serial response time tasks have both perceptual and motor learning components and require the subject to respond to a stimulus such as light, with some motor response, such as touching it. In research studies the subject must attend to an array of 4 or more stimuli. The subject is instructed only to respond as quickly as possible to whichever stimulus lights up over a number of trials. What is not explained to the subject is that practice is organized in 2 ways i.e. random & repeating sequence. Subjects are said to demonstrate learning of the pattern if their response time decreases during trials with the repeating sequence and increases during subsequent trials with the random sequence. Subjects are questioned after practice is complete and if they report not having noticed any sequence or pattern, their learning is said to be implicit. Other subjects may gain explicit knowledge of the task and report that they noticed something about the task. Some subjects may have recognition and recall regarding the actual pattern of the sequence and can recognize the pattern when it is displayed or can reproduce it without cuing, their learning is said to be explicit10.

Would explicit information provided prior to practice facilitate implicit motor sequence learning in patients of stroke during acute stage?

Methods

This chapter deals with the methodology implemented to conduct the following study. This section provides detailed information on the type of study design, sampling technique, procedure, and protocol of data collection.

Sample Size of sample

A total of 22 subjects with anterior circulation stroke (diagnosed by neurologist) were included in the study. In the group A (No-Explicit Information group) 13 subjects were recruited (total 15 subjects were recruited, but 2 patients left in between). In the group B (Explicit Information Group) 9 subjects were recruited.

Source of sample

VIMHANS Hospital, New Delhi

Method of selection

Inclusion criteria9, 10, 12

Method of selection

Inclusion criteria9, 10, 12

1. Anterior circulation stroke
2. Both right & left sided stroke
3. First ever stroke
4. Post stroke duration less than three months
5. Both males and females
6. Age 50 to 80 years
7. Right hand dominance
8. Medically stable
9. Able to sit independently (Clinical Outcome Variables Scale item no 4 i.e. COVS≥5)
10. Able to understand and follow commands (Mini Mental Status Examination i.e.MMSE≥26)

Exclusion criteria9, 10, 11

1. Neurological disorder other than stroke (e.g. Parkinson's disease, head injury, multiple sclerosis etc.)
2. History of any psychiatric illness
3. Musculoskeletal problem of upper limb that would be used to perform the task (e.g. Pain, stiffness, fracture, arthritis)
4. Any nerve injury of upper extremity that would be used to perform the task
5. Uncorrected visual or hearing loss
6. Any sensory deficit in the upper extremity used for performing the tas

7. Perceptual deficit after stroke (screened by neuropsychologist.

8. MMSE<24 (Score of less than 24 on MMSE)

Method of sampling

Sample was selected through convenient sampling method and subjects were randomly assigned through lottery method to the group.

Study Design: Posttest only experimental study design, Instrumentation and tools for data collection:

Equipment's

1. RT (Reaction time) Apparatus (RTM 608) manufactured by Medicaid system Chandigarh, Punjab.
2. Table and chair of average height.

Measurement tools

1. Mini Mental Status Examination (MMSE) scale.

2.Clinical Outcome Variables Scale (COVS) scale.

Procedure

22 subjects were recruited on the basis of inclusion and exclusion criteria and were assigned to eachgroup. Participants were explained about the purpose and nature of study. They were instructed to press the start switch as they are ready and then respond to the appropriate and corresponding stimulus as quickly as possible. Informed consent was obtained from all the subjects after matching for inclusion and exclusion criteria. Data (response time) was collected in a room free from distractions and was recorded in the data collection form.

Protocol

The apparatus was placed on a table of appropriate height and subject was made to sit on a chair facing the apparatus with arm supported on table or arm rest.

The hand ipsilateral to the brain damage was used to perform the given task. Subjects were asked to place their index finger of the ipsilateral hand over the reference point on the apparatus and move it to the subsequent lights which would glow and take their finger back to the reference point after pressing the appropriate button. Three colored lights (Red i.e. R, Green i.e. G, and Yellow i.e. Y) were displayed on the apparatus; illumination of one of the lights was the stimulus for the subjects. Following the cue to respond, participants responded by pressing the appropriate button corresponding to the light so pressing the correct key extinguished the light. Subjects were instructed to respond as quickly as possible.

All subjects practiced the same fixed and repeating 10 element sequence (Y,G,R,G,Y,R,G,R,Y,G). This sequence was constructed to be ambiguous, such that there were minimal probability relationships among its elements. The beginning and end of each sequence were not marked, so that the transition between sequences was seamless. Each block of responses was composed of 3 repetitions of the sequence that is 30 responses. An initial block of random responses was practiced (30 responses). Next, four blocks of repeating sequence were practiced (120 responses). Finally, subjects performed one last block of the random sequence. In sum, subjects practiced the repeating sequence for 4 blocks (120 responses) and made random responses for 2 blocks (60 responses). A short break of 30 seconds to 1 minute was provided at the end of each block of responses. This practice pattern (i.e. 1 random block, 4 repeating block, 1 random block) was repeated on three consecutive days. On day 4, retention tests were given to assess learning of the serial reaction time task. Retention was measured by performance of one block of the repeating sequence.

In group A (Non EI group) subjects were kept unaware of the sequence being practiced and in group B (EI group) subjects were provided explicit information regarding sequence pattern prior to practice. For those subjects in the explicit group i.e. EI group, day 1 consisted of practice only. On day2, participants in the EI group were informed that there was a repeating sequence in some of the practice trials. On day 3, participants in the EI group were explicitly instructed regarding the existence and composition of the repeating sequence. For those in the implicit group i.e. No-EI group, day 1, 2 and 3 consisted of practice only, no explicit information regarding the sequence was provided.

Three levels of explicit knowledge were tested, subjective awareness of the existence and composition of the sequence, recognition memory, and recall memory. Subjective memory was tested by asking subjects if they noticed anything about the task. Recognition memory test determined if the subjects would be able to correctly identify the repeating sequence after watching it be played on the screen. Recall was tested to ascertain if subjects knew the repeating sequence well enough to correctly predict what element of it would come next when viewing a fragment of the 10 elements (i.e. 3 elements). The delivery and content of explicit instructions for each group are detailed by day and group in the appendix E.

Results

Descriptive statistics is used to analyze subject characteristics. 22 subjects recruited for the study were randomly assigned to each group, group A (Non EI) with 9 males and 4 females with mean age of 59.94 years and mean score on MMSE, & COVS, were 27.92 and 6.00. Group B (EI) with 8 males and 1 female with mean age of 58.22 years and mean score on MMSE, & COVS were 29.00 and 6.56.

On comparing the Age (p=0.75), MMSE score (p=0.09), and COVS score (p=0.08) between the two groups, the results were not significant (at $p<0.05$). Thus both the groups are comparable.

Table 5.1: Comparison of age, MMSE and COVS for group A (Non EI group) and group B (EI group)

Variables	Group A (Non EI) Mean ± Standard deviation	Group B (EI) Mean ± Standard deviation	p value
Age	59.54 ± 10.94	58.22 ± 6.62	0.75
MMSE	27.92 ± 1.18	29.00 ± 1.73	0.09
COVS	6.00 ± 0.70	6.56 ± 0.72	0.08

Within Group Comparison (Group A) Of Day 1, 2, 3, & 4

The mean and standard deviation of first random block of day 1 is 2.55 ± 1.11, mean of all the repeating sequence of day 1 is 2.13 ± 1.03, and sixth random block of day 1 is 2.06 ± 0.91. The difference between first random block and mean of all the repeating

The mean and standard deviation of mean of all the repeating sequence of day 1 is 2.13 ± 1.03, mean of all the repeating sequence of day 2 is 2.07 ± 0.99, mean of all the repeating sequence of day 3 is 1.92 ± 0.93, and retention test on day 4 is 1.82 ± 0.69. There is no significant difference between mean of all the repeating sequence of day 1 & retention test on day 4 and all the other four variables.

Table 5.2: Comparison of repeating reaction time (average of day 1, 2, & 3) and retention test (day 4) of group A (No EI group)

Variables	Mean ± Standard deviation	p value
D1REP	2.13 ± 1.03	-
D2REP	2.07 ± 0.99	-
D3REP	1.92 ± 0.93	-
D4RET	1.82 ± 0.69	-
DIREP vs D2REP	-	1.00
D1REP vs D3REP	-	1.00
D1REP vs D4RET	-	0.86
D2REP vs D3REP	-	1.45
D3REP vs D4RET	-	1.00

With in- Group Comparison (Group B) Of Day, 1, 2, 3, & 4

The mean and standard deviation of first random block of day 1 is 2.04 ± 0.52, mean of all the repeating sequence of day 1 is 1.71 ± 0.27, and sixth random block of day 1 is 1.78 ± 0.49. The difference between first random block of day 1 and mean of all the repeating sequence of day 1 is significant (at $p<0.05$), there is also significant difference between first random block of day 1 & sixth random block of day 1 (at $p<0.05$). However the difference between mean of all the repeating sequence of day 1 & sixth random block of day 1 is not significant

Between group comparison of retention test

The mean & standard deviation of retention test on day 4 of group A is 1.82±0.69 and of retention test on day 4 of group B is 1.41±0.16. There is no significant difference between the retention tests of both the groups.

Table 5.3: Comparison of retention test (day 4) of group A (Non EI) and group B (EI)

Variables	Group A (Non EI) Mean ± Standard deviation	Group B (EI) Mean ± Standard deviation	p value
D4RET	1.82 ± 0.69	1.41 ± 0.16	0.10

Explicit knowledge testing of group B (EI group)

Subjective awareness- In the EI group, when the explicit knowledge was tested at the end of day 1 of practice, 33.3% of the subjects stated that they noticed some degree of repetition in their responses for the SRT task. However this value is below the chance i.e. it may be due to guessing.

Recognition - At the end of day1 none of the subjects were able to recognize the sequences. By the end of day 2 of practice, recognition remained below chance (44.4%). After giving the full explicit information on the day 3 prior to practice, the recognition improved to 88.9% i.e. above chance and at the end of the practice all the subjects were able to recognize the sequences (100%).

Recall –Recall remained below chance over the three consecutive days (0%, 11.1%, 33.3%, and 44.4%). Despite giving full explicit information on the day 3, recall did not improve at the end of practice (44.4%) i.e. it indicates that they are guessing.

Table 5.4: Explicit knowledge testing of group B

	Subjective awareness % noticed (N= 9)	Recognition % noticed (N= 9)	Recall % noticed (N= 9)	
Day 1	33.3%	0 %	0 %	Day 1
Day 2	-	44.4 %	11.1%	Day 2
Day 3 (pre practice)	-	88.9 %	33.3 %	Day 3 (pre practice)

Scores below 50 % indicate responding at or below (i.e. guessing)

Discussion

Our experimental hypothesis was that explicit information would affect the implicit motor sequence learning in the acute stage of stroke. As the results reveal, the experimental hypothesis was accepted i.e. subjects provided with explicit information (EI group) demonstrated better learning of implicit motor learning task, than that of the subjects those not provided with explicit information (Non EI group). The inability of subjects post anterior circulation stroke to demonstrate implicit learning when they were not aware of the sequence shows deficits in implicit motor sequence learning during the acute stage. Implicit learning is thought to occur when changes in performance occur as the practice conditions change, such as a change from the repeating sequence to the random sequence. The inclusion of a retention test is compatible with the motor learning literature in which learning is said to exist only with relatively permanent changes in behavior. We tried to distinguish between short term performances related changes in behavior and long term learning by administering a retention test on day 4. We found significant improvement in reaction time of subjects in EI group evident at retention test, suggesting beneficial effect of explicit information on implicit motor sequence learning.In both EI and Non EI groups on the day 1, we observed a significant improvement in the reaction time as the subjects switched from random to the repeating sequences but that change almost remain unchanged when the subjects again performed the last i.e. 6th random block. This type of improvement in performance did not appear on the next two days i.e. day 2 and day 3 in both the groups (EI & Non EI group). In the Non EI group, there was significant improvement in reaction time of first random block on day 1 & 2. In the EI group, there was significant improvement in reaction time of first random block on day 2 & 3. This could be attributed to the novelty of the task on day 1 for the subjects, but on subsequent days there motivation would have gone down. It may be assumed that the subjects were motivated initially but after practicing the few blocks their motivational level came down. Another factor contributing to this could be the environment; it might be possible that subjects got accustomed to the environment after experiencing few blocks & so their performance remained same on subsequent days.

Explicit learning involves four different types of processing, including encoding, consolidation, storage, and retrieval. The extent of the processing is determined by the level of motivation, attention, and the ability to associate it meaningfully with information that is already in memory8. Our results of explicit knowledge testing of EI group demonstrate that albeit subjects are able to take advantage of explicit information to improve their performance on implicit motor learning task, but they are not able to recall or express it. Even after giving full explicit information on the day 3, the recall of the subjects did not improve i.e. remained below chance. However recognition of the subjects improved significantly on the day 3. This shows although the learning of EI group improved but they were not able to express the learning explicitly.

The results suggest that subjects might recruit the explicit memory system to augment the performance on an implicit motor sequence learning task, when implicit learning deficits resulting from acute stroke are present. The fact that these deficits are attenuated by the provision of explicit knowledge prior to physical practice supports previous work in motor learning post stroke in which subjects received feedback and detailed instructions regarding strategies for successful task completion. Following stroke it has been shown that subjects are able to learn new motor skills. In general, however research that has examined motor learning in adults with stroke, focusing on the instructions given to engage learners in explicit learning suggest that subjects with stroke are able to learn at an explicit level10. Our findings also support previous work by Boyd and Winstein11. They suggested that if the areas which are responsible for implicit learning (for e.g sensori-motor cortex) are damaged following stroke, then explicit memory may be recruited to improve performance on the implicit motor learning task.

However our findings contradict the work by Boyd and Winstein9, 46, in their experiments explicit information had detrimental effect during acquisition performance. The primary motor cortex (PMC) has a strong role in regulating sequence production when learners are provided explicit information and the primary motor cortex (PMC) has strong connections with the prefrontal regions associated with explicit memories i.e. dorsolateral prefrontal cortex and is reciprocally interconnected with the basal ganglia. It is quite likely that damage to, & in regions associated with the primary motor cortex (i.e. MCA infarct, Basal Ganglia stroke) results in disrupted integration of explicit information into planned sequence of movement and inability to take advantage of explicit information during implicit motor sequence practice. They also suggested that explicit information might block formation of the implicit motor plan due to the increased demand placed on the working memory system. Our results also contradict the work of Green and Flowers, they found that instructions prior to practice actually degraded implicit learning of a computer simulated probabilistic catching task. However, this interference effect may be due to the task complexity.

Research literature has shown that the effect of explicit information on implicit learning may depend on the type, timing, and meaningfulness of the information provided. It appears that explicit and implicit learning sometimes develops in parallel and can profoundly affect each other. Further the interaction between the implicit learning and explicit learning may be critical following acute stroke. Implicit learning may rely on the sensori-motor cortex whereas explicit memory does not; perhaps in the presence of stroke related brain damage it may be recruited to improve performance. Finally, our findings together with previous motor learning findings in stroke suggest that explicit information given prior to practice can benefit the implicit motor sequence learning in individuals with anterior circulation stroke during acute stage of strok

In therapy, when helping patients with acute stroke reacquire skills the therapist should emphasize on explicit learning. Teaching movement skills explicitly would allow patients to rehearse their movements mentally, increasing the amount of practice available to them, therefore improving the acquisition performance.

Conclusion

Our findings suggest that explicit information when given prior to physical practice improved implicit motor sequence learning in subjects with acute stroke; however subjects were not able to express it explicitly.

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